UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

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BULLETIN 468

May, 1929

UNIVERSITY OF CALIFORNIA PRINTING OFFICE
BERKELEY, CALIFORNIA
1929

STERILIZATION OF DAIRY UTENSILS WITH HUMIDIFIED HOT AIR

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That the use of humidified hot air furnishes an efficient and satisfactory means of sterilizing dairy utensils is the conclusion to be drawn from a series of experiments carried on cooperatively by the Agricultural Engineering and Animal Husbandry Divisions of the University of California. Humidified hot air was found to have a bactericidal efficiency equivalent to that obtained when live steam was used. Moreover, the utensils were left free from moisture. The energy consumption was less than when either the steam boiler method or the steam electric unit was used. The system was found to be practical of operation, except that it furnished no hot water for washing utensils.

Sterilizing dairy utensils is usually accomplished by the application of live steam at approximately 210° Fahrenheit for 20 minutes. Although, strictly speaking, the process does not result in complete destruction of all organisms, especially the more resistant spore formers, this interpretation of sterilization is accepted generally by the dairy industry. The five more important methods in use at the present time are designated, according to the means of applying the heat, as the steam boiler; self-contained oil burner; wood or oil furnace; steam electric; and dry hot air types. The first four of these employ steam as the sterilizing medium. The chief objection to the use of this medium lies not in the incomplete destruction of the organisms at 210° F for twenty minutes, but in the fact that the vessels are often left moist after sterilization has been completed. This condition is conducive not only to recontamination and further growth of organisms, as shown by Prucha and Harding,[3] but also to a rusting of the vessels.

The need for a practical method of sterilization that will avoid this residual moisture led investigators to the use of dry hot air. Ayres

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[3] Prucha, M. J., and H. A. Harding. The elimination of germs from dairy utensils, Illinois Agr. Exp. Sta. Bul. 230:1–168. 1920

and Mudge[4] concluded that both a bacterial reduction, sufficient for dairy purposes, and resulting dry equipment can be secured by the application of hot air at 230° F for a period of 30 minutes. With this method, however, no hot water is available for other purposes. Moreover, it has not been received favorably by the industry.

Although all five types are fairly satisfactory under certain conditions, none is free from objections. The steam boiler method, which is extremely practical of operation, has a high initial cost and is expensive to install and operate. As shown by Farrall[5] though both the self-contained oil burner and the wood or oil furnaces are relatively inexpensive from the standpoints of first cost, installation, and upkeep, they are difficult to operate because of the smoke, oil, and soot accompanying their use. The steam electric, in which a submerged electrical unit is used, has the disadvantages of requiring excessive energy for operation and close attention to prevent burning out the elements. Dry hot air, in which the electric element operates in the atmosphere, is relatively low in initial and installation costs, upkeep, and energy required. Difficulties in construction, together with unequal heating, however, are its main disadvantages.

Any method approaching the ideal must require only a relatively short operating period for each sterilization, not to exceed 70 minutes, and must leave on the utensils the smallest number of viable organisms possible. According to Prucha, Weeter, and Chambers,[6] this number should not exceed one hundred per c.c. for a full 10-gallon can. Furthermore, the apparatus must be relatively low in initial and installation costs, upkeep, and energy required; it must be easy to clean and practical to operate; and, upon completion of the sterilization process, it must leave the vessels free from moisture. It must be so constructed that the possibility of burning out the heating elements, or of overheating the equipment sterilized, is at a minimum.

An attempt was made, therefore, as reported in this bulletin, to evolve a type of sterilizer that would comply as nearly as possible with these specifications. Because of the recognized superiority of moist heat in its bactericidal action, humidified hot air (a mixture of hot air and superheated water vapor) was selected as a sterilizing medium. It was thought, moreover, that the use of moisture would minimize the formation of low temperature air pockets within the sterilizer and equipment—an objection that obtains with the use of hot dry air. Elec-

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[4] Ayres, S. Henry, and Courtland S. Mudge. Hot air sterilization of dairy utensils. Jour. Dairy Sci. 4:79–90. 1921.

[5] Farrall, A. W. Operating characteristics of dairy sterilizers. Agr. Engineering, 8:143, 237, 273, 341. 1927.

[6] Prucha, M. J., H. M. Weeter, and W. H. Chambers. Germ content of milk; II As influenced by the utensils. Illinois Agr. Exp. Sta. Bul. 204:1–80. 1920.

tric elements appeared to offer the best means of heating because of their adaptability to the method, being difficult to burn out and effective in heating air, and because of their low costs, cleanliness, and freedom from odors.

To determine the value of this method, its operation was compared with that of other types of known efficiency. Because of the serious objections to the furnace, the self-contained oil burner, and the dry hot air types mentioned in the preceding paragraph, it was decided to limit the comparisons to the steam boiler and steam electric methods.

APPARATUS USED

In figure 1 is shown the 4 x 4 x 5 foot galvanized iron tank, which, when connected with a 5-horsepower steam boiler, served in the daily sterilization of the milk utensils at the University dairy barn. With modifications, this tank was used in all three methods of sterilizing compared in this experiment. When steam was generated by the submerged electric unit (the steam electric method) instead of in the boiler, three 5-kilowatt immersion type heaters were fitted in its sump and 80 pounds of water added, completely covering the elements.

Figure 2 shows the heating device with which the tank was equipped to conduct the humidified hot air trial. This device consisted of eighteen 500-watt electric air heaters, so placed underneath the perforated baffles (*A*) that they forced most of the air to circulate toward the sides of the tank and then upward. A heater was fitted underneath each of the two shallow pans (*B* and *B′*) located just above the baffles. When in operation, this heating unit was placed in the sump of the tank, and one quart of water poured into each pan. When the current was turned on, the water in the pans evaporated, forming steam which mixed with the heated air in the sterilizer.

METHOD OF CONDUCTING THE STUDY

A series of tests was planned, in which each of the three methods of sterilizing was to be tried under similar conditions. The following measurements were made:

1. Time and temperature relationships within the sterilizer box.
2. Power and energy requirements.
3. Bactericidal efficiency.
4. Moisture remaining on apparatus and utensils after sterilization.
5. Practicability of operation.

Each test was repeated three or more times under the same load and under uniform conditions.

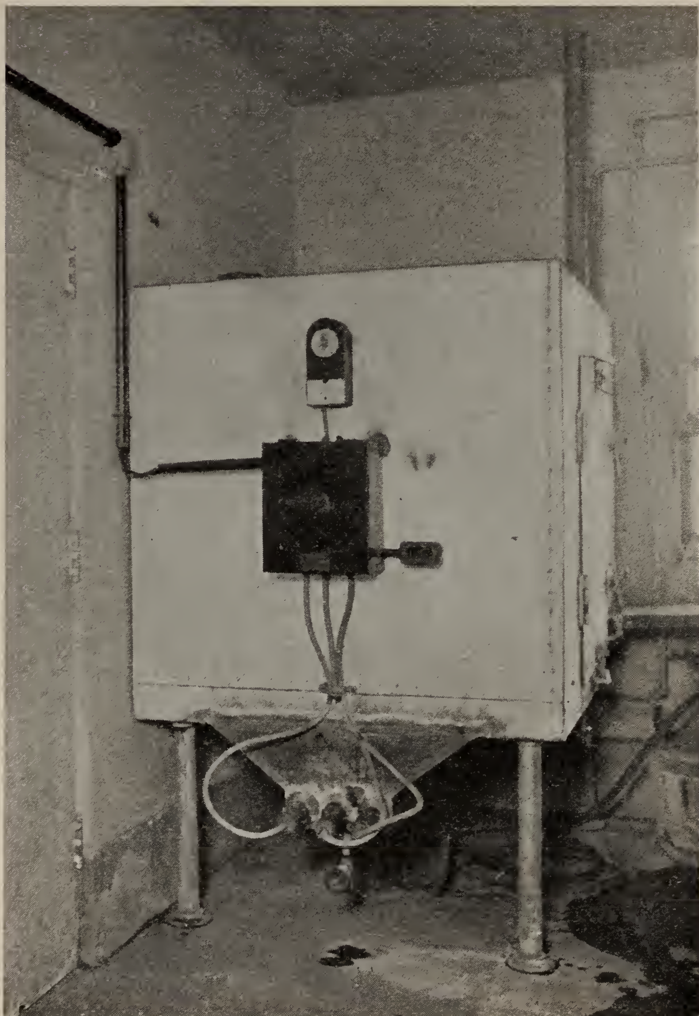

Fig. 1.—Galvanized iron sterilizer box, showing sump and electrical connections.

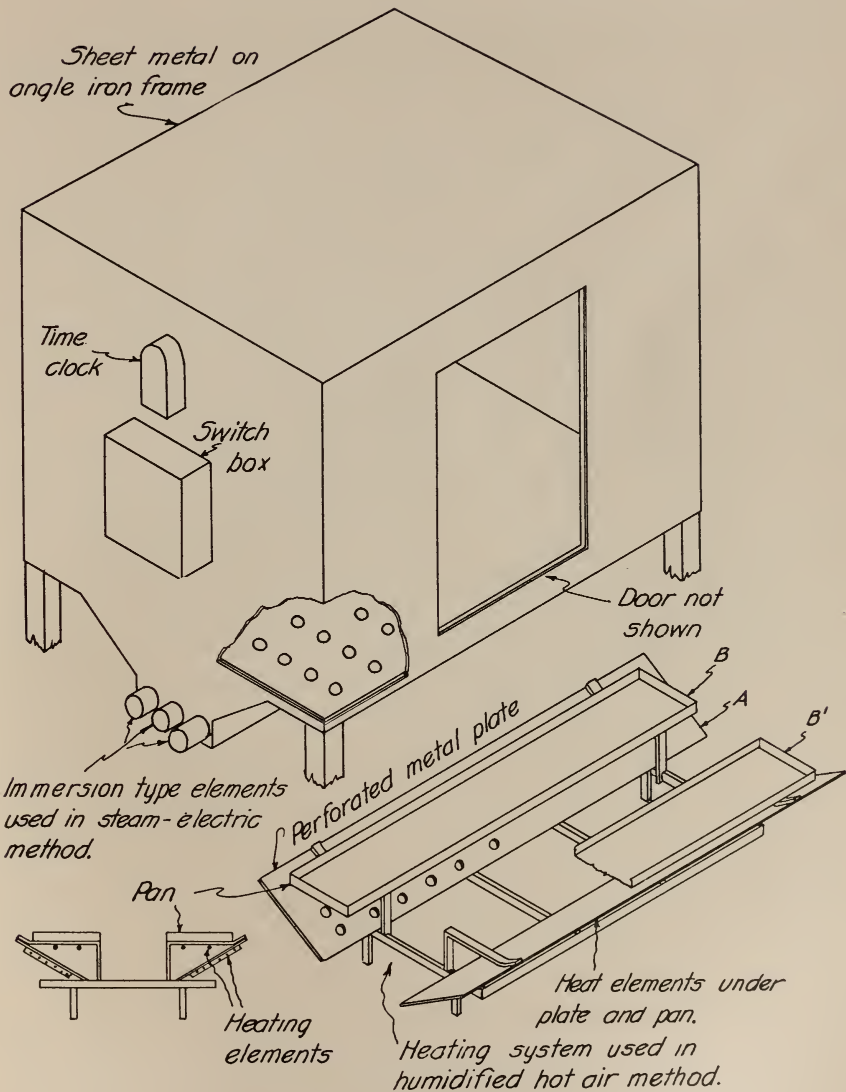

Fig. 2.—Detail of heating device.

TABLE 1

SUMMARY OF STERILIZER TESTS

Test method	Room temperature, deg. Fahr.	Time in minutes		Size of heater	Energy required		Bacteria count			
							5-gal. pail		10-gal. can	
		To reach 210° Fahr.	Above 210° Fahr.		Consumed	Cost at 1.5 cents per kw.h.	Before	After	Before	After
Humidified hot air, test 1	74.0	50.0	20	9.08 kw.			272	1	263	1
Humidified hot air, test 2	72.0	63.0	20	9.36 kw.			‡	1	‡	1
Humidified hot air, test 3	54.0	50.0	20	10.30 kw.*			*11	1	‡	17
Average	*66.6*	*54.0*	*20*	*9.58 kw.*	*11.87 kw.h.*	*17.81c*				
Steam electric method, test 1	78.5	50.0	20	16.49 kw.			120	7	‡	100
Steam electric method, test 2	80.3	55.0	20	15.87 kw.			27	1	26	4
Steam electric method, test 3	86.0	50.0	20	16.37 kw.			893	1	570	3
Average	*81.6*	*51.0*	*20*	*16.24 kw.*	*19.2 kw.h.*	*28.80c*				
Steam boiler method, test 1	81.3	62.5	20	5 h.p.			‡	2	‡	6
Steam boiler method, test 2	76.2	80.0	20	5 h.p.			‡	2	‡	43
Steam boiler method, test 3	72.5	87.0	20	5 h.p.			124	1	134	26
Average	*76.6*	*76.5*	*20*	*5 h.p.*	*26.9 lb.*†	*23.35c*†				

* Extra heating elements added   † Stove oil used—6 cents per gallon   ‡ Not countable.

DATA OBTAINED FROM THE TESTS

A summary of the results is given in table 1. From it, comparisons can be made of such items as power and energy requirements, rate of heating, and bactericidal efficiency.

The relationship between time and temperature is controlled largely by the rate at which energy is applied. In these tests, however, an attempt was made to balance the heating units so that the results would be comparable.

Temperatures were measured by means of a chemical thermometer inserted through the top of the sterilizer near the center, 1½ feet from the front. As shown in table 1, a temperature of 210° F was reached in 54 minutes with the humidified hot air method, a 9.58 kw. heater being used; in 51.0 minutes with the 16.24 kw. steam electric type; and in 76.5 minutes with the steam boiler. This last figure includes the time required to secure a pressure of 80 pounds on the boiler, consuming approximately 67 minutes.

From the typical time and temperature curves of figure 3, several facts are evident. Curve C shows that while the actual time for heating the sterilizer by the steam boiler method was but 12.5 minutes, 70 minutes were necessary for steaming up the boiler, thus making a total of 82.5. The maximum temperature was 212° F. The same maximum was attained with the steam electric method, but the heating was more rapid, requiring only 58 minutes. Though it was somewhat slower when humidified hot air was used (*curve A*), this fact is not significant, because even with the smaller heating element, 9 kw. as compared with 16 kw., only 15 minutes more were consumed; and in addition, the steam was superheated, since the temperature rose above 212° F. The bactericidal efficiency was thus increased, and the time requirement above 210° F was decreased.

Much importance is rightly attached to the uniformity with which the sterilizer and utensils heat. In order to check this point, eight thermocouples were placed in different parts of the sterilizer. With both the steam boiler and steam electric types of heating, the temperature remained almost uniform after 200° F had been reached. There were slight variations, however, with the humidified hot air while the sterilizer was warming up. These variations as they occur during a typical run are shown in figure 4.

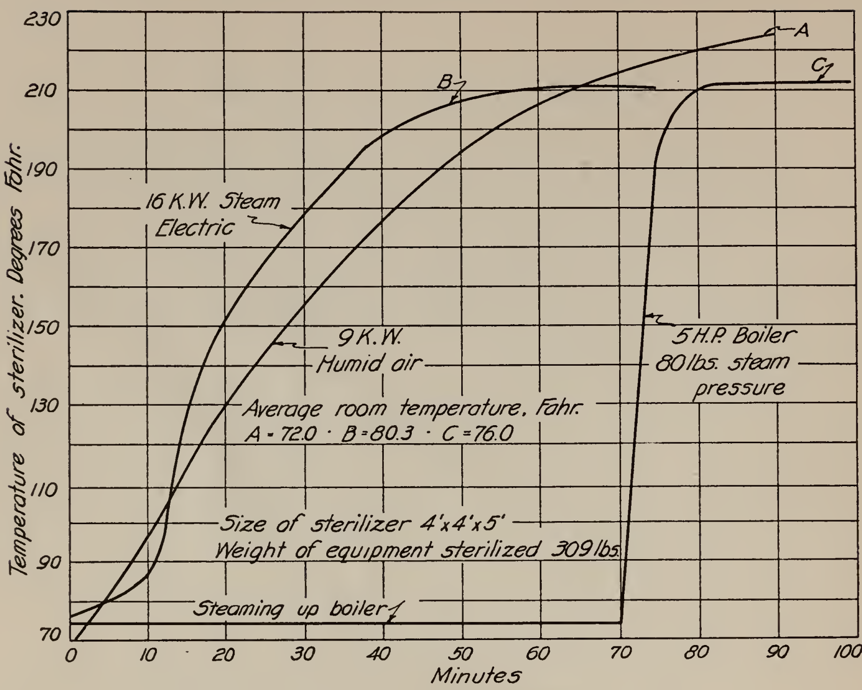

Fig. 3.—Typical time and temperature curves.

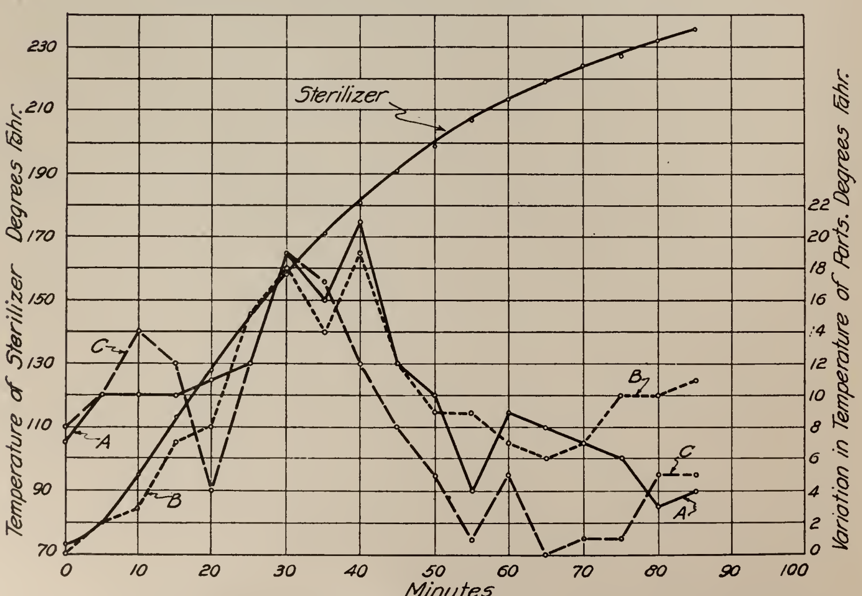

Fig. 4.—Variations of temperature within the sterilizer. *A*. Differences in temperature between a point near the upper left side of the tank and a point near the bottom of the door. *B*. Differences in temperature between a point at the center of the sterilizer and a point near the door. *C*. Differences in temperature between the can metal and the air on the left side near the top.

Curve *A* was plotted from differences in temperature found at two points, one near the upper left side of the tank, and the other near the bottom of the door. Curve *B* was made from differences in temperature found at a point near the door and another at the center. After the sterilizer reached 200° F, the variation, according to curve *A,* ranged from 3° to 10°; according to curve *B,* from 6° to 11°. It is evident, then, that the air near the door was not much cooler than that at the center.

Curve *C* shows that the temperature of the utensils followed closely that of the air, the difference being from 0° to 8°, after the 200° mark was reached. Although these figures are large enough to be significant if only 212° F is obtained, their importance is nullified by higher temperatures. A specially designed sterilizer box having no square corners should greatly facilitate even thermal distribution and eliminate temperature pockets.

COST OF ENERGY

The costs of energy for the three different methods are listed as follows in table 1, current prices being used: by humidified hot air, 17.81 cents; by steam electric, 28.80 cents; by steam boiler, 23.35 cents. The greater economy of the humidified hot air type is due to the smaller connected load and to the fact that little water must be heated. A sterilizer box properly insulated would materially lessen even the figure given above. It would not, however, effect a similar saving with the steam boiler method, since the tank is heated for only a short time at each sterilization. Insulating the boiler itself, however, would be advantageous.

MOISTURE ON UTENSILS

Utensils left moist after sterilization deteriorate by rusting, become easily recontaminated, and furnish conditions favorable for bacterial growth. Measurements for residual moisture, therefore, were made during these tests by the following procedure: Two 10-gallon cans were thoroughly dried, placed in the tank, and sterilized with the lids removed. When the process was completed, the door was opened. Two minutes later, the lids were replaced and the cans removed. After they were cool, a petri dish containing a weighed amount of concentrated sulphuric acid was placed in each can for twenty-four hours to absorb the moisture, and was then reweighed.

Table 2 shows the average weights of moisture remaining in a can to be 0.67 grams for the humidified hot air method, and 9.36 grams for the steam boiler method.

It was observed when using humidified hot air that almost immediately after the door was opened, all the utensils, as well as the lower part of the sterilizer, appeared to be very dry. Inverted 10-gallon cans were found to have some vapor, as would be expected. Those lying on their sides, however, and shallow cans in an upright position had no visible moisture; it was always evident on those sterilized by the steam boiler method.

TABLE 2

MOISTURE REMAINING IN TEN-GALLON MILK CANS AFTER STERILIZATION

Steam boiler method		Humidified hot air method	
Can No.	Grams of water	Can No.	Grams of water
1	6.47	1	.80
2	17.85*	2	.80
3	6.30	3	.70
4	6.85	4	.40
Average	9.36	Average	0.67

* Because this can was directly in front of a steam jet, excessive moisture was collected.

BACTERICIDAL EFFICIENCY

That bacterial reduction was satisfactory with the humidified hot air method, is evident from table 1. Counts were made by plating one cubic centimeter from a 400 c.c. water blank. At each sterilization, four counts were taken from the equipment which consisted of one 10-gallon milk can and one 5-gallon milking machine pail. Samples were taken both before and after sterilization.

PRACTICAL OPERATION OF THE HUMIDIFIED HOT AIR STERILIZER

The sterilizer was given a thorough, practical test by being in constant use twice daily from September 19 to November 12, 1928. The bacteria count of the milk at no time exceeded 10,000 bacteria per c. c., thus indicating that satisfactory sterilization was being accomplished. One beneficial result observed was the elimination of steam from the sterilizer room. There seemed to be no detrimental effects upon the equipment or apparatus, except in one instance, when the automatic time switch failed to turn off the power, and the sterilizer operated continuously for three hours. The only result then was the

melting of some solder from a few utensils placed on the bottom of the sterilizer near the heater. This was not considered a serious matter, as installation of a safety device would prevent excessive temperatures. A larger sump to contain the heating elements would, furthermore, effect more satisfactory thermal distribution.

A separate heater furnished hot water, for the humidified hot air sterilizer does not lend itself readily to such a purpose. At the completion of the investigation, the heating unit of the sterilizer was removed and tested thoroughly. It was found to be free from shorts, grounds, and burn-outs. Two of the elements, which were of different make from the others, scaled off. When tested, they proved to be made of a soft material, which was evidently unsatisfactory. None of the other elements showed signs of wear or of excessive heating.

CONCLUSIONS

1. Humidified hot air has several advantages over the steam boiler and steam electric methods of sterilization:
   - *a.* It is equivalent to live steam in bactericidal action.
   - *b.* It is less expensive to operate electrically.
   - *c.* It leaves the equipment dry, or practically so.
   - *d.* It is much less liable to the burning out of elements and is therefore safer to operate.
   - *e.* It has a low depreciation.
   - *f.* It does away with excessive steam in the sterilizer room.
2. The disadvantages of the method are:
   - *a.* Some temperature variations occur within the sterilizer, but are not great enough to affect its practicability.
   - *b.* No hot water for washing utensils is furnished.
3. Practical operation over a period of two months indicated that humidified hot air is a satisfactory and effective medium for sterilizing dairy utensils.
4. There is need for simple and effective thermostats, time switches, and high temperature cut-outs for use with this method.

ACKNOWLEDGMENTS

The writers wish to express their appreciation to Dr. C. S. Mudge, of the Dairy Industry Division, for his valuable assistance in determining the bactericidal efficiency of methods of sterilization compared in this bulletin.

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